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Effects of anxiety on running with and without an aiming task

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Abstract

State anxiety is known to affect far aiming tasks, but less is known about the effects of state anxiety on running and aiming while running. Therefore, in the current study participants ran on a treadmill at their preferred speed in a low- and high-anxiety condition. In both conditions, running was combined with dart throwing in the last minutes. Results showed that attention shifted away from task execution with elevated levels of anxiety. Furthermore, gait patterns were more conservative and oxygen uptake was higher with anxiety. In addition, performance and efficiency on the dart throwing task also decreased with anxiety. These findings are in line with attentional control theory and provide an indication that state anxiety not only affects aiming tasks but also tasks that rely heavily on the aerobic system. Moreover, findings indicate that when combined, running, aiming, and anxiety all compete for attention leading to suboptimal attentional control and possibly a decrease in performance.

Keywords: Aerobic exercise, attentional control theory, dart throwing, gait, perceptual-motor tasks

Introduction

In competitive sport and other high-achievement settings, humans often experience high anxiety, which may affect their task execution and performance. A theory that provides an explanation for the mechanisms behind the effects of state anxiety on task execution is attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), a recent extension of processing efficiency theory (PET; Eysenck & Calvo, 1992). Attentional control theory proposes that there are two attentional systems: a top-down, goal-directed system, and a bottom-up, stimulus-driven system (Corbetta & Shulman, 2002). With anxiety, the balance between the two systems is disrupted in favour of the stimulus-driven system. As a result, anxiety facilitates attention towards detecting the threat that causes the anxiety and thereby shifts attention away from task execution (Eysenck et al., 2007). Such shifts in attention can lead to a decrease in task efficiency, and possibly performance, as less attention is available for actual task execution. As an example, penalty kick performance in soccer players deteriorated when state anxiety was induced (Wilson, Wood, & Vine,

2009b). In line with attentional control theory, this drop in performance was accompanied by shifts in visual attention from the goal target area towards the goalkeeper, which is a potential threat to scoring a penalty in soccer.

According to attentional control theory, anxiety does not necessarily lead to a decrease in performance. It is suggested that negative effects of anxiety can be compensated for by the investment of additional attentional resources and extra mental effort. As a result, efficiency of task execution (called processing efficiency) decreases but performance may be maintained. For example, it was shown for rally driving (Wilson, Chattington, Marple-Horvat, & Smith, 2007) and volleyball (Smith, Bellamy, Collins, & Newell, 2001) that people invested more mental effort when they were anxious (showing a decrease in processing efficiency) yet performance was maintained.

Whether task execution is affected by anxiety depends on the degree to which task execution relies on working memory (Eysenck et al., 2007). Tasks that rely heavily on working memory are expected to be more vulnerable to performance breakdown than tasks that are controlled almost entirely outside of

working memory (Eysenck & Calvo, 1992). Much research on attentional control theory is concerned with cognitive tasks, as these often rely heavily on working memory. However, findings that support attentional control theory are available for perceptual-motor aiming tasks such as penalty kicks (Wilson et al., 2009b), skeet (Causer, Holmes, Smith, & Williams, 2011), handgun (Nieuwenhuys & Oudejans, 2010), and basketball shooting (Wilson, Vine, & Wood, 2009a). Yet, many of the sports in which aiming tasks are important, such as soccer, basketball, and handball, also contain a large aerobic component; that is, many of these tasks are combined or interchanged with physical exertion often in the form of running. Whether and how state anxiety affects running and far aiming while running remains unclear. Therefore, in the current study we investigated the effects of anxiety on running alone and on running combined with dart throwing.

For running, movement control is generally viewed as highly automated with marginal use of cognitive resources (Hausdorff, Yogeve, Springer, Simon, & Giladi, 2005). However, a growing body of literature indicates that walking and running do address attentional resources. Lindenberger and colleagues (Lindenberger, Marsiske, & Baltes, 2000) tested participants performing a memory task while walking, while sitting, and while standing. Performance on the memory task decreased during walking compared with sitting and standing. Also, more missteps (steps outside the outlined walking track) were made when walking was combined with the memory task. Furthermore, in several other studies, stride frequency was found to increase (Ebersbach, Dimitrijevic, & Poewe, 1995) and stride length to decrease (Nadkarni, Zabjek, Lee, McIlroy, & Black, 2010; Yang, Chen, Lee, Cheng, & Wang, 2007) when walking was combined with a secondary cognitive task. Apparently, although highly practiced, gait is not completely automated and still demands attention (cf. Abernethy, Hanna, & Plooy, 2002). If running, just as walking, also requires attention, and state anxiety disturbs attentional control, then one would expect state anxiety to also affect running efficiency. Regarding the effects of anxiety, Brown and colleagues (Brown, Doan, McKenzie, & Cooper, 2006) provided support for this suggestion for walking. They imposed anxiety by manipulating imbalance when participants walked on a walkway. This manipulation consisted of elevating the walkway, reducing the width of the walkway, and a combination of the two. Brown et al. observed that stride and step length reduced with anxiety and concluded that with anxiety participants adopted a more conservative gait pattern to reduce the risk of falling.

To date, few researchers have investigated the relationship between state anxiety and the aerobic

demands of running. Martin and colleagues (Martin, Craib, & Mitchell, 1995) investigated the relationship between oxygen uptake and *trait* rather than *state* anxiety of 18 competitive distance runners during submaximal treadmill running. No correlation was found between trait anxiety and oxygen uptake. Acevedo and colleagues (Acevedo, Dziewaltowski, Kubitz, & Kraemer, 1999) did manipulate state anxiety with a challenging video while trained endurance runners ran on a treadmill at submaximal speed. No effect of anxiety on oxygen uptake was found. However, an increase in anxiety was only visible for a short period at the beginning of the anxiety condition, suggesting that participants performed most of the anxiety condition under an anxiety level that was comparable to that of the no-anxiety condition. In short, as Martin et al. (1995) did not investigate state anxiety and Acevedo and colleagues' (1999) manipulation of state anxiety had methodological limitations, the question whether state anxiety affects running remains unanswered. Nonetheless, several studies have shown that the aerobic system can be influenced by psychological factors, such as relaxation and attentional focus (Caird, McKenzie, & Sleivert, 1999; Eaves, Hodges, & Williams, 2008; Martin et al., 1995; Schücker, Hagemann, Strauss, & Volker, 2009). Schücker et al. (2009), for instance, found that different foci of attention (internal or external) during running led to differences in oxygen uptake. Similarly, Eaves et al. (2008) found that running under different conditions of visual attention (dynamic mirror image, dynamic reversed mirror image, and a static image) led to differences in running kinematics and oxygen uptake. In short, although there are indications that anxiety affects walking and that psychological factors such as attentional focus may affect running, the direct effects of state anxiety on running still need to be investigated.

In the current study, we had participants run and throw darts while running in two anxiety conditions, high and low above the ground. Height has previously been applied successfully to induce anxiety (e.g. Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008; Pijpers, Oudejans, & Bakker, 2005). To get an indication of whether changes in attention occurred with anxiety, participants provided retrospective verbal reports about their attentional focus during both anxiety conditions. Furthermore, we measured running efficiency. Running efficiency is commonly operationalized by running economy, which is defined as the energy demand for a given velocity of submaximal running (Daniels, 1985). An individual who runs at the same speed as another individual but consumes less oxygen is said to run more efficiently. We also measured gait parameters that can provide additional indications of running

efficiency. Saunders and colleagues (Saunders, Pyne, Telford, & Hawley, 2004) argued that running economy at a certain speed is the highest at a runner's self-selected stride length, and that oxygen uptake increases when the runner's stride length becomes either longer or shorter. Finally, we measured efficiency and performance of dart throwing.

Following attentional control theory, anxiety is predicted to shift attention away from running (and dart throwing) towards threat-related stimuli (e.g. worries; Eysenck et al., 2007). To compensate for this possible shift in attention, participants are expected to invest more mental effort in an attempt to remain focused on the task (Eysenck et al., 2007). Due to these changes in efficiency, we expected alterations in gait parameters and running economy (Brown et al., 2006; Schücker et al., 2009). More specifically, with anxiety, stride length is expected to decrease, while stride frequency and oxygen uptake are expected to increase (Ebersbach et al., 1995; Nadkarni et al., 2010). Perceived physical effort is expected to be higher with anxiety due to changes in gait parameters and running economy. Performance on the dart throwing task is expected to decrease and dart times are expected to increase with anxiety (Oudejans & Pijpers, 2009, 2010). Finally, as both anxiety and dart throwing are expected to consume attention, and thus evoke changes in gait parameters and running economy, we expect the changes in these parameters to be largest when running is combined with both dart throwing and anxiety.

Methods

Participants

A total of 19 students (11 women, 8 men) with a mean age of 21.6 years ($s = 1.2$) participated in the study. They were informed of the procedures of the experiment and they all provided informed consent prior to participation. The local ethics committee approved the experimental protocol. The participants completed the Dutch version of the A-trait scale of the State-Trait Anxiety Inventory (STAI; Van der Ploeg, Defares, & Spielberger, 1980). The mean trait score for the women (mean = 34.8, $s = 6.1$) was not significantly different from the mean score for Dutch female students (mean = 37.7; Van der Ploeg et al., 1980) ($t_{10} = 1.57$, $P = 0.147$). The mean trait score for men (mean = 28.4, $s = 4.0$) was significantly lower than the mean score for Dutch male students (mean = 36.1; Van der Ploeg et al., 1980) ($t_7 = 5.51$, $P = 0.001$). These scores imply that the participants were normal to low in trait anxiety and therefore had no extraordinary tendency to respond across many situations with high state anxiety. All participants had experience with

treadmill running. Participants had no experience with dart throwing or performing at height.

Study design

All measurements were carried out on the same day. The study consisted of two conditions (low and high anxiety) of 10 min each with 10 min rest between conditions. Before the two experimental conditions, participants ran for 10 min on a treadmill (which was placed on a platform on the floor) and threw 12 practice darts three times to become accustomed to treadmill running and the aiming task and to determine their preferred running speed. This predetermined speed would be the participants' constant running speed throughout the experiment. Exercise of 15 min duration on a treadmill has been shown to be sufficient to accommodate to treadmill running (Schieb, 1986; Wall & Charteris, 1980, 1981). The accommodation time was reduced to 10 min in our study since all participants had experience with treadmill running. After the accommodation period, participants ran for 10 min at the predetermined constant speed in the low-anxiety and high-anxiety condition in a counterbalanced design. In both conditions, participants ran for 8 min (run phase) followed by a combined running and dart throwing phase (dart phase) during which they threw 12 darts.

Materials and measures

Anxiety manipulation. Anxiety was manipulated through height. Two identical small and narrow motorized treadmills (Bremshey Sport Path treadmill, length = 175 cm, width = 75 cm) were placed on a platform 20 cm above the ground and on a narrow scaffold (Upright Ireland, length = 200 cm, width = 80 cm) 4.2 m above ground level (see Figure 1). The arm rails were removed from the treadmills and the scaffold. In both conditions, the participants wore a full-body safety harness. In the high-anxiety condition, the harness was attached to a coupling that was anchored to the ceiling above the scaffold to prevent falling. In the low-anxiety condition, the safety harness was anchored to a batten, which was fixed on the scaffold. In both conditions, an emergency stop was attached to the harness that caused the treadmill to stop when participants moved too far to the rear end of the treadmill.

Subjective measures. After each condition, participants completed a 10 cm continuous visual-analogue scale to measure the anxiety experienced during that condition. The anxiety scale ranges from 0 ("not at all anxious") to 10 ("extremely anxious"). The

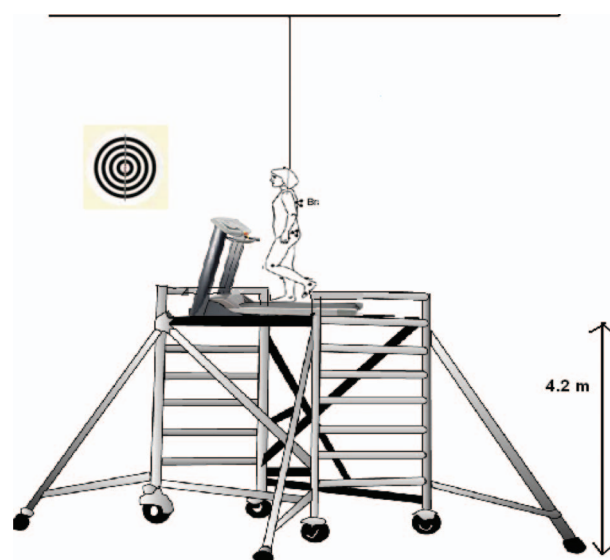


Figure 1. Experimental set-up of the high-anxiety condition.

anxiety scale, also called the “anxiety thermometer”, was validated by Houtman and Bakker (1989) and has been successfully used previously (e.g. Nieuwenhuys & Oudejans, 2010). Each individual was provided with a new scale after each condition. Although the anxiety thermometer does not differentiate between cognitive and somatic anxiety, Bakker and colleagues (Bakker, Vanden Auweele, & Van Mele, 2003) showed that anxiety thermometer scores correlate equally with the cognitive and somatic anxiety scores on the CSAI-2.

Zijlstra’s (1993) Rating Scale of Mental Effort (RSME) was used to assess the amount of mental effort participants perceived they had invested in the running task. This vertical scale ranged from 0 (“absolutely no effort”) to 150 mm (“most effort ever”). The RSME was shown to be valid and reliable by Veltman and Gaillard (1993) and has been used successfully previously (e.g. Eaves et al., 2008).

The Dutch translation of the Borg Scale (Borg, 1982) was used to measure participants’ ratings of perceived exertion (RPE). The Borg Scale ranges from 0 to 10, with 0 reflecting total rest and 10 corresponding to maximal perceived exertion.

Attentional focus. After the experiment, participants were asked to write down where they focused attention during both running conditions. Following Oudejans and colleagues (Oudejans, Kuipers, Kooijman, & Bakker, 2010), statements on attentional focus were selected from the verbal reports and then grouped into five categories: movement execution, distracting thoughts and worries, external task-relevant (e.g. statements concerning the treadmill or the dartboard), external task-irrelevant (e.g. statements concerning noises in the background), and positive monitoring (statements such as: “I try to

score as high as possible”). The statements about where participants focused their attention were analysed and grouped by two independent observers. The inter-observer reliability was 90%.

Metabolic measures. Respiratory gases and heart rate were analysed using the K4 system (COSMED, Rome, Italy). Running economy, defined as whole-body energy expenditure at standard submaximal speeds (O_2 consumption in $\text{mL} \cdot \text{min}^{-1}$), was determined. To ensure that energy expenditure (and therefore running efficiency) was not compromised by anaerobic exercise, the respiratory exchange ratio (RER) was not allowed to exceed 1.00 (McArdle, Katch, & Katch, 2006, p. 243).

Kinematic measures. Gait parameters were measured using two foot switches (MA-153 event switches, Motion Lab Systems, Baton Rouge, LA) that were connected to an EMG recording system (Porti 17, Twente Medical Systems; 500 Hz sample rate). The switches were attached with duct tape under the heel and toe of the left shoe of the participant and were not removed between conditions. Contact time (time between initial heel contact and toe-off), stride frequency, and stride length (running speed divided by stride frequency) were determined from the heel strike and toe-off data.

Dart task. In the dart throwing phase, one dart board (diameter = 0.46 m) was used in both conditions. The dart board was attached at the official competition height and distance (1.74 m above running surface, throw line at about 2.37 m from the dart board) and could be moved from the low to the high condition and vice versa. The dartboard contained ten black and white circles varying in points. Bull’s-eye corresponded to 10 points. The score decreased by 1 point per circle when moving away from the bull’s-eye. The darts were placed in a cup that was attached to the treadmill near the participants’ dominant hand. No points were assigned for darts that missed the board. Participants were instructed to throw 12 darts and to score as many points as possible. A “beep” provided by the experimenter announced the start of the dart throwing phase. Participants took the darts from the cup one dart at a time. The average score per dart was calculated as a measure of performance. Dart efficiency was assessed through dart time, which was defined as the amount of time the participant took to throw the 12 darts.

Procedures

Upon arrival, participants were informed of the procedures. They gave their written informed

consent and completed the STAI. Foot switches were attached to their left shoe, the K4 was put on, and participants' baseline heart rate was measured. Then, participants took position on the low treadmill and the accommodation condition started. Participants ran for 10 min, chose their preferred speed, and practised dart throwing. After the accommodation condition, participants sat down on a chair and rested until their heart rate had returned to baseline values. Subsequently, participants took position on the treadmill for either the low-anxiety or high-anxiety condition. The scaffold in the high-anxiety condition was reached by a 5 m high mobile footbridge. Participants were fitted with the safety harness and started their first running condition. They ran at their predetermined speed and after 8 min a "beep" announced the start of the dart throwing phase. Participants threw 12 darts. Dart times and dart scores were recorded. At the end of a condition, speed was slowly reduced to $0 \text{ km} \cdot \text{h}^{-1}$. Participants immediately completed the anxiety thermometer, RSME, and Borg scale. Then, they stepped off the treadmill and sat down. Between conditions, participants rested for 10 min to ensure that their heart rate returned to baseline values. After the last condition, they completed the report about the focus of attention during running.

Data analysis

Chi-square tests were performed on the number of statements on attentional focus per category in the low-anxiety and high-anxiety condition. Furthermore, two-tailed paired *t*-tests were performed to assess the effects of condition (low anxiety, high anxiety) on anxiety scores, mental effort scores, RPE, dart scores, and dart time. Gait parameters, oxygen uptake, and heart rate were submitted to 2×2 (Condition [low anxiety, high anxiety] \times Phase [run, dart]) repeated-measures analyses of variance.

Results

Table I provides an overview of the mean values (and standard deviations) of the main variables.

Manipulation check

Participants reported significantly more anxiety in the high-anxiety than in the low-anxiety condition ($t_{18} = 5.94$, $P < 0.001$, $d = 1.36$, 95% CI [2.2, 4.7]). Perceived mental effort was also significantly higher in the high-anxiety than in the low-anxiety condition ($t_{18} = 2.41$, $P = 0.027$, $d = 0.55$, 95% CI [1.9, 27.3]). Average RPE did not differ between conditions ($t_{18} = 0.83$, $P = 0.415$).

Table I. Mean values (and standard deviations) for perceived effort, exertion and anxiety, dart performance, oxygen uptake, heart rate, and gait parameters during treadmill running in low- and high-anxiety conditions.

| | Condition | |
|--|--------------|--------------|
| | Low anxiety | High anxiety |
| Anxiety Scores*** | 1.4 (1.1) | 4.8 (2.2) |
| RSME* | 44.1 (26.6) | 58.6 (21.8) |
| RPE | 3.3 (1.6) | 3.5 (1.3) |
| Oxygen uptake ($\text{ml} \cdot \text{min}^{-1}$)* | | |
| run phase | 2240 (256) | 2297 (280) |
| dart phase | 2391 (263) | 2464 (326) |
| Heart rate ($\text{beats} \cdot \text{min}^{-1}$)* | | |
| run phase | 161.7 (17.6) | 166.9 (15.5) |
| dart phase | 169.6 (16.8) | 173.3 (14.0) |
| Stride frequency ($\text{strides} \cdot \text{min}^{-1}$)*** | | |
| run phase | 77.2 (4.3) | 78.1 (4.3) |
| dart phase | 77.6 (4.5) | 79.2 (4.2) |
| Stride length (cm)*** | | |
| run phase | 157.3 (11.3) | 155.2 (10.7) |
| dart phase | 156.3 (10.8) | 152.9 (9.4) |
| Contact time (ms)** | | |
| run phase | 287.0 (37.1) | 298.0 (37.8) |
| dart phase | 291.9 (34.1) | 306.5 (40.4) |
| Dart score (per dart)* | 5.2 (1.1) | 4.6 (1.6) |
| Dart time ($\text{s} \cdot \text{dart}^{-1}$)** | 4.5 (1.1) | 5.0 (1.3) |

Note: RSME = Rating Scale of Perceived Mental Effort, RPE = rating of perceived exertion.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Attentional focus

The numbers and percentages of the statements on attentional focus are listed in Table II. Attentional focus was significantly different in the low-anxiety than in the high-anxiety condition ($\chi^2(12) = 153.0$, $P < 0.001$). Worry and distracting thoughts were mentioned significantly more often in the high-anxiety than in the low-anxiety condition ($\chi^2(1) = 6.533$, $P = 0.011$).

Gait parameters

Recording of the toe-off data failed for five participants. Therefore, contact times could not be determined for these participants. There was a significant main effect of condition on stride frequency ($F_{1,18} = 26.28$, $P < 0.001$, $\eta_p^2 = 0.60$), stride length ($F_{1,18} = 26.14$, $P < 0.001$, $\eta_p^2 = 0.59$), and contact time ($F_{1,13} = 19.18$, $P = 0.001$, $\eta_p^2 = 0.60$). Stride frequency was higher in the high-anxiety condition ($1.3 \text{ strides} \cdot \text{min}^{-1}$, 95% CI [0.8, 1.9]), whereas stride length was shorter (2.7 cm, 95% CI [1.6, 3.9]) and contact time longer (12.8 ms, 95% CI [6.5, 19.1]) in the high-anxiety condition (see Table I). There was also a significant main effect of phase on stride frequency ($F_{1,18} = 7.03$, $P = 0.016$, $\eta_p^2 = 0.28$), stride length ($F_{1,18} = 7.46$, $P = 0.014$,

Table II. Numbers and percentages of statements on attentional focus during treadmill running in low- and high-anxiety conditions.

| | Condition | | | |
|----------------------------------|----------------------|------------|----------------------|------------|
| | Low anxiety | | High anxiety | |
| | Number of statements | Percentage | Number of statements | Percentage |
| Movement execution | 6 | 13.6 | 9 | 17.7 |
| Worries and distracting thoughts | 8 | 18.2 | 22 | 43.1 |
| External – task-relevant | 15 | 34.1 | 13 | 25.5 |
| External – task-irrelevant | 7 | 15.9 | 2 | 3.9 |
| Positive monitoring | 8 | 18.2 | 5 | 9.8 |
| Total | 44 | 100.0 | 51 | 100.0 |

$\eta_p^2 = 0.29$), and contact time ($F_{1,13} = 10.60$, $P = 0.006$, $\eta_p^2 = 0.45$). Stride frequency was higher in the dart throwing phase ($0.8 \text{ strides} \cdot \text{min}^{-1}$, 95% CI [0.2, 1.4]), whereas stride length was shorter (1.7 cm , 95% CI [0.4, 2.9]) and contact time longer (6.7 ms , 95% CI [2.2, 11.1]) in the dart throwing phase (see Table I). There were no significant interactions.

Running economy and heart rate

Participants' average running speed was $7.3 \text{ km} \cdot \text{h}^{-1}$ (range: $7.0\text{--}7.8 \text{ km} \cdot \text{h}^{-1}$). Their respiratory exchange ratio (RER) remained below 1.00 (mean = 0.91, $s = 0.05$), indicating that all participants exercised predominantly in the aerobic domain. In the run phase, mean values for oxygen uptake and heart rate were calculated for minutes 3 to 8. The first 2 min were excluded since the participants were trying to optimize their equilibrium during this starting phase (Schücker et al., 2009).

For oxygen uptake there were significant main effects of condition ($F_{1,18} = 5.55$, $P = 0.030$, $\eta_p^2 = 0.24$) and phase ($F_{1,18} = 62.31$, $P < 0.001$, $\eta_p^2 = 0.78$). Oxygen uptake was higher in the high-anxiety condition ($65 \text{ ml} \cdot \text{min}^{-1}$, 95% CI [7.1, 123.5]) and in the dart throwing phase ($159 \text{ mL} \cdot \text{min}^{-1}$, 95% CI [116.9, 201.6]) (see Table I). There was no significant interaction.

Recordings of heart rate failed for two participants. For the remaining participants, heart rate showed significant main effects of condition ($F_{1,15} = 6.55$, $P = 0.022$, $\eta_p^2 = 0.30$) and phase ($F_{1,15} = 27.28$, $P < 0.001$, $\eta_p^2 = 0.65$). Heart rate was higher in the high-anxiety condition ($4.1 \text{ beats} \cdot \text{min}^{-1}$, 95% CI [0.7, 7.5]) and in the dart throwing phase ($6.6 \text{ beats} \cdot \text{min}^{-1}$, 95% CI [3.9, 9.2]) (see Table I). There was no significant interaction.

Dart scores and dart time

Dart scores were significantly lower in the high-anxiety than in the low-anxiety condition ($t_{18} = 2.26$,

$P = 0.036$, $d = 0.52$, 95% CI [0.1, 1.1]). Dart times were significantly longer in the high-anxiety than in the low-anxiety condition ($t_{18} = 2.94$, $P = 0.009$, $d = 0.67$, 95% CI [0.2, 0.9]).

Discussion

In the current study, the effects of state anxiety on running and combined running and dart throwing were investigated. First, perceived state anxiety was significantly higher when running on a treadmill high on a scaffold than when running on a treadmill near the ground. Second, as expected, participants seemed to focus their attention more on worries and distracting thoughts with than without anxiety. Third, there were several indications that efficiency was affected by anxiety as more mental effort was invested, oxygen uptake and heart rate were higher, and gait parameters changed. Fourth, just as in previous studies on anxiety and aiming, dart throwing was also affected by anxiety (e.g. Oudejans & Pijpers, 2009, 2010; Vickers & Williams, 2007; Wilson et al., 2009a, 2009b). Dart performance was significantly lower and performance times were higher with anxiety. Finally, dart throwing itself also affected oxygen uptake, heart rate, and running parameters, implying an accumulated effect of anxiety and dart throwing.

As for attention, in line with attentional control theory, anxiety seemed to distract attention away from task-related information towards task-irrelevant stimuli (i.e. worries; Eysenck & Calvo, 1992; Eysenck et al., 2007). Whereas in the low-anxiety condition participants' attentional focus was mostly directed at the dart board and the treadmill (task-related information), thoughts in the high-anxiety condition were more about preventing falling (threat-related worries). These changes in attentional focus provide a first indication that attentional control shifted from goal-directed to stimulus-driven during running with anxiety (Eysenck et al., 2007; cf. Oudejans et al., 2010). It seems that participants found it difficult to disengage from worrying about

falling off the scaffold. Further research with more explicit measures of attention (e.g. gaze behaviour) is needed to provide more insight into the mechanisms through which attentional control changes when running under stressful circumstances.

Anxiety and the accompanying changes in attention led to less efficient running, even though running, just as walking, is often considered to be highly automated. That mental effort was higher with anxiety suggests that processing efficiency was reduced, which is in line with attentional control theory (Eysenck et al., 2007). The higher oxygen uptake or higher energy expenditure with anxiety means that running is less efficient. Similar changes in running economy have also been found by Schücker et al. (2009) with different attentional focus instructions. Schücker et al. found that running was less efficient with an internal focus of attention than with an external focus of attention. This supports our idea that the changes we found in running economy were related to the changes in attention, from task-relevant external matters to threat-related internal worries.

The higher energetic costs with anxiety are likely the result of the changes in gait parameters. With anxiety stride frequency was significantly higher and contact times were longer, whereas stride length was shorter, resembling a more conservative gait pattern (Barak, Wagenaar, & Holt, 2006; Brown et al., 2006; Maki, 1997). In other studies, metabolic costs were found to be higher when participants ran with a gait pattern other than the preferred one (Cavanagh & Williams, 1982; Dallam, Wilber, Jadelis, Fletcher, & Romanov, 2005). Note that the instructed running speed in the current study was also the “preferred” one. Anxiety may have pushed runners out of their preferred mode into less efficient running. In this process, movements may have become more rigid (Beuter & Duda, 1985; Pijpers, Oudejans, Holsheimer, & Bakker, 2003), possibly contributing to the higher energetic costs of running. This fits with the ideas of Hatfield and Hillman (2001) and Janelle and Hatfield (2008), who addressed psychomotor efficiency and found that anxiety induces less efficient motor cortex activity, resulting in constrained and inhibited movement patterns. Despite the increases in heart rate and oxygen uptake, participants’ perceived physical exertion did not increase with anxiety. As self-report scales are not as sensitive as physiological measures, it is possible that the physiological changes observed in the current study may not have been large enough to elicit changes in Borg scale scores.

An additional increase in perceived mental effort and longer performance times in the high-anxiety condition suggest that performance on the dart throwing task was less efficient with anxiety. Despite

the extra mental effort invested, dart performance deteriorated with anxiety. Similar results have been reported by Causer et al. (2011) for skeet shooting, Nieuwenhuys and Oudejans (2011) for handgun shooting, and Wilson et al. (2009a, 2009b) for basketball and penalty shooting, respectively. Causer et al. (2011), for example, showed that with anxiety, shooters had less efficient gun motion and higher mental effort scores as well as decreased shooting performance. Causer et al. suggested that the drop in performance was caused by a decrease in goal-directed attention as participants’ final fixation on the skeet became shorter with anxiety (cf. Nieuwenhuys & Oudejans, 2011; Wilson et al., 2009a, 2009b). In the current study, the available attentional resources might not have been sufficient to address attention towards worries, running, and dart throwing simultaneously, an interpretation that would again be in line with attentional control theory. When running was combined with both anxiety and dart throwing, the effects of anxiety and dart throwing seemed to accumulate, showing the largest values on all kinematic and consequently metabolic variables in this combined condition (except of course for stride length where it elicited the lowest value). These findings are consistent with earlier findings by Williams and colleagues (Williams, Vickers, & Rodrigues, 2002), who reported accumulating effects of anxiety and task complexity (i.e. high and low attentional demands) on performance accuracy, reaction time, and invested mental effort in table tennis.

In conclusion, state anxiety not only affects perceptual-motor aiming tasks, but also tasks that rely heavily on the aerobic system, such as running. With anxiety, running kinematics became less efficient, resulting in higher energetic costs. Furthermore, when tasks that rely on the aerobic system and aiming tasks are combined an accumulated effect occurs, implying that running, aiming, and anxiety all compete for attention, leading to suboptimal attentional control and a decrease in performance. Further studies are needed to investigate whether these findings generalize to exercise with different intensities, different stressors, and different task combinations, especially because there are several fields in which high-intensity running is combined with aiming tasks, such as ball sports, but also police work, fire fighting, and military operations. An important question that remains is if and how the negative effects of anxiety in those tasks may be countered. Recent studies by Oudejans and colleagues on aiming tasks without running (dart throwing, basketball free throw shooting, and handgun shooting) show that training with elevated levels of anxiety holds promise in this regard (Nieuwenhuys & Oudejans, 2011; Oudejans, 2008; Oudejans &

Pijpers, 2009, 2010). Whether training with anxiety is also effective in preventing negative effects of anxiety in tasks that rely heavily on the aerobic system needs to be established in future research.

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